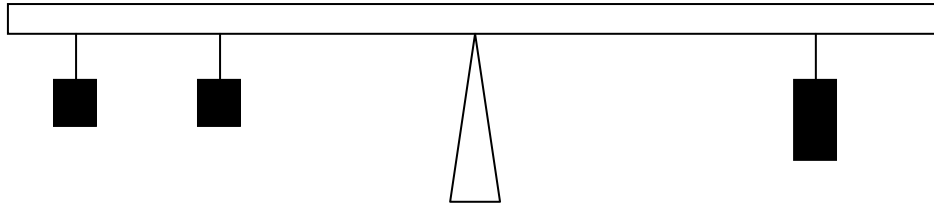


Centre of Gravity and Torque

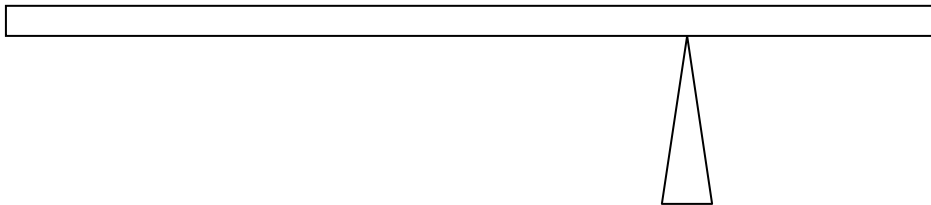
A classic example of a torque arrangement is the teeter-totter balance. Weights placed on one side of the balance pivot provide a torque to rotate the balance one way. To counter this, weights are placed on the other side of the pivot to provide a torque in the opposite direction. You may even have performed this lab in Physics 11.



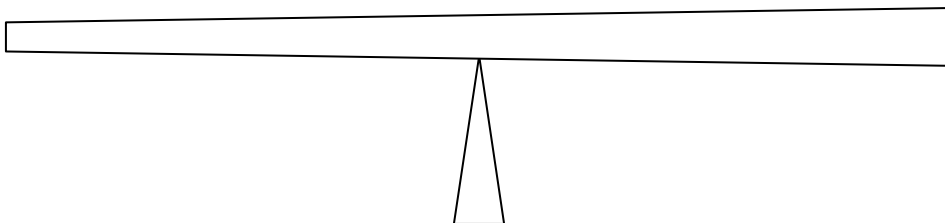
When calculating torque here, the weight of the three hanging masses must be determined, along with their respective distances from the pivot. However, one weight which is being overlooked is the weight of the beam itself, which can be ignored so long as:

- the beam is so light that its weight and resultant torque can be ignored; or
- the beam is of a *uniform* shape so that the pivot can be placed at the centre of the beam, creating balance before weights are added to either side.

However, sometimes the pivot may not be placed at the centre of a uniform beam:



Or perhaps the beam itself is not of a uniform shape:



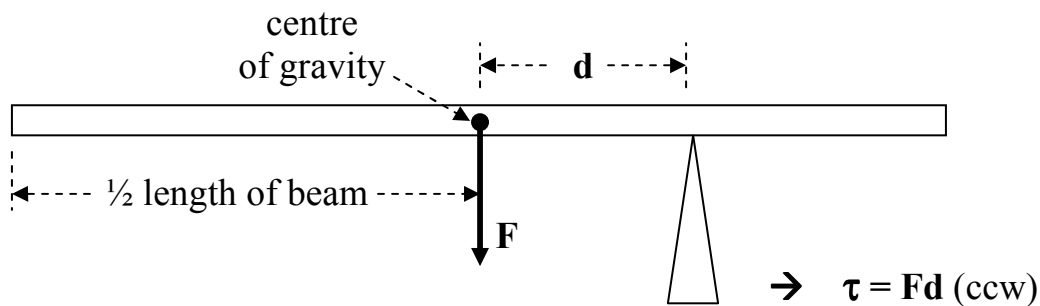
In each of these two situations, it seems clear that rotation will occur due to the weight of each beam. In order to calculate the torque that causes each rotation, the following must be known:

- the weight of the beam;
- the *centre of gravity* of the beam, in order to determine the distance of the weight away from the pivot.

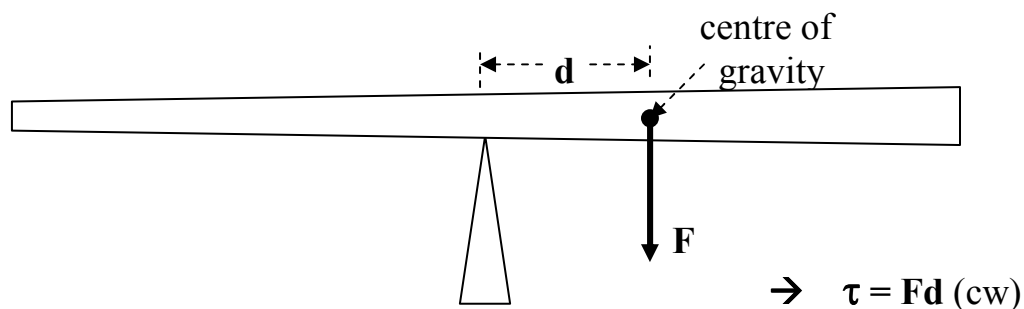
The centre of gravity is simply the location where an object will have its weight evenly distributed on either side. When the object is rotating in air or space, it will do so about its centre of gravity. When a pivot is placed at this location, the object will be balanced, and no torque will occur.

Knowing the location of the centre of gravity of any object is useful, because it allows you to place the weight vector at that location, which in turn allows you to calculate the torque created. Note that the centre of gravity is always located at the mid-point of any uniform object.

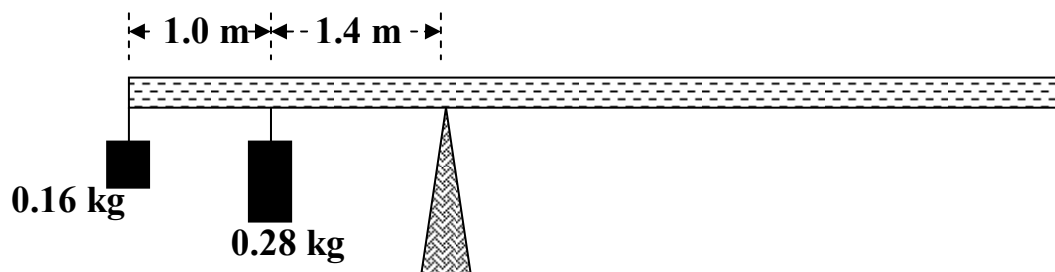
For a uniform beam:



For a non-uniform beam (centre of gravity must be indicated in the question):

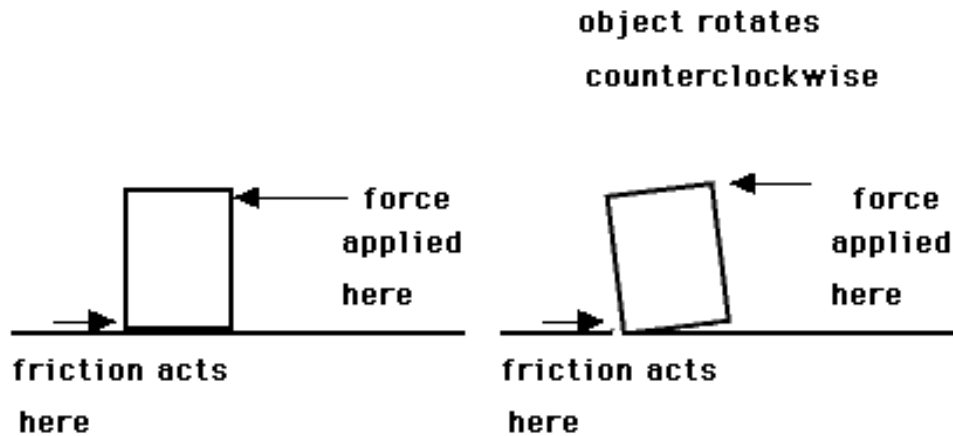


Example #9: Calculate the net torque acting in the system below. Note that the beam is uniform, has a mass of 0.85 kg, and a length of 6.2 m.



(see Equilibrium Ex 9 for answer)

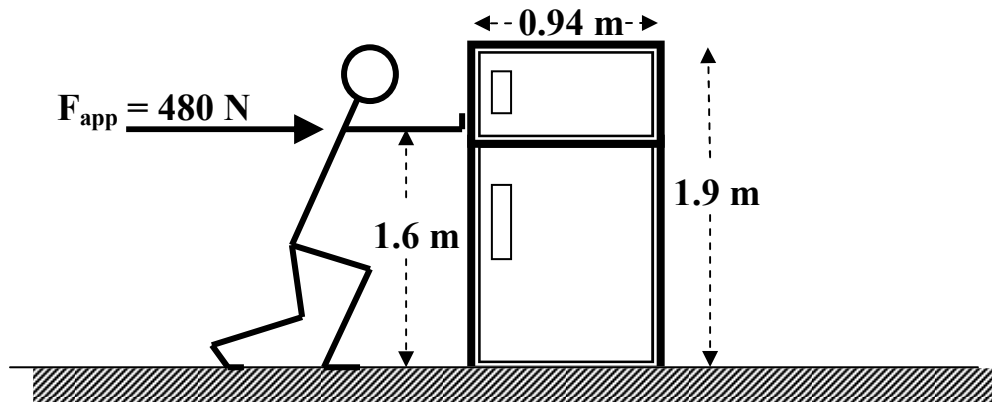
Now let's review the idea of non-concurrent forces. Non-concurrent forces occur not only on beams, but also on three-dimensional objects such as heavy crates that are pushed along the floor. As before, if the line of action of each force does not pass through a common point, then a net torque may exist, causing the object to start to rotate and ultimately tip over.



In the example above, the applied force produces a counter-clockwise torque about the lower-left corner pivot, while the centre-of-gravity of the object creates a clockwise torque about the same pivot. If the applied force is large enough, or high enough up from the pivot, the object will rotate in a counterclockwise direction, pivoting around its lower-left corner.

Note that as the object starts to tilt, both the friction force (shown in the diagram) and the normal force (not shown) act at the pivot. Therefore, these two forces produce no torque.

Example #10. A physics student applies a horizontal force of 480 N in an attempt to move a 150 kg refrigerator, but unfortunately causes the fridge to tip over. Examining the diagram below, what is the net torque that causes the refrigerator to begin to topple over?



(see Equilibrium Ex 10 for answer)